# Air Quality Forecasting Tools

## OVERVIEW

- Background
- Acquiring historical data
- Forecasting tools (examples, strengths/weaknesses)
  - Climatology
  - Statistical
  - Modeling

Details on developing forecasting methods are provided in the Ozone and $PM_{2.5}$ Forecasting Guidance Document (U.S. Environmental Protection Agency, 2003).

# Background

- Forecasters use a variety of data products, information, tools, and experience to predict air quality.
- Forecasting tools:
  - Subjective
  - Objective
- Tools provide information to help guide the forecasting process.
- Forecasting tools are built upon an understanding of the processes that control air quality.
- More forecasting tools = better results.

# Background

Tool development is a function of:

- Amount and quality of data (AQ and meteorological)
- Resources for development (human, software, computing)
- Resources for operations (human, software, computing)

Types of tools:

- Persistence
- Climatology*
- Criteria, Thresholds, Rules of thumb
- Regression equations*
- Classification and Regression Trees (CART)*
- Neural networks
- Fuzzy logic
- Numerical modeling*
- Conceptual and experience

Fewer resources, lower accuracy

More resources, potential for higher accuracy

*Discussed in this course

# Acquiring Historical Data (1 of 2)

Sources

- Air Quality Data
  - EPA's AIRS database
  - AIRNow (regional images)
- Meteorological Data
  - See Appendix for list of data sources
  - Soundings and surface observations
  - Data and weather maps
  - Trajectories
  - Satellite images

# Acquiring Historical Data (2 of 2)

## Sample size

- Acquire 3 to 5 years of data
- Be aware of changes in emissions (fuel changes, new sources, new monitors)

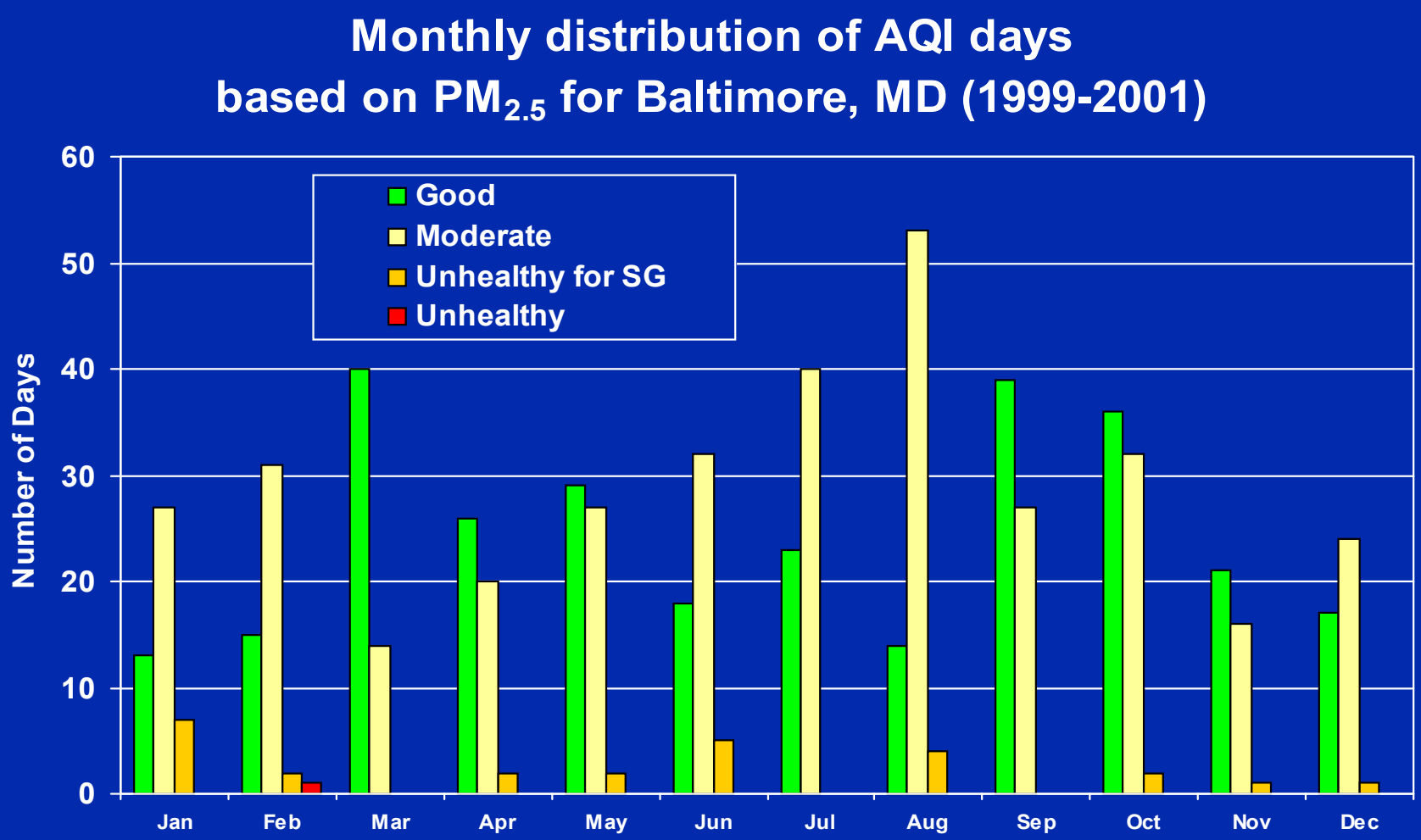
## Other issues

- Time standard and units
  - Air quality data are usually in Local Standard Time
  - Meteorological data are usually in UTC
  - Concentrations in $\mu g/m^3$, ppm, ppb
- Data quality
  - Review data for quality prior to use
- Data completeness
  - 75% of data are needed to compute daily, monthly, and annual averages

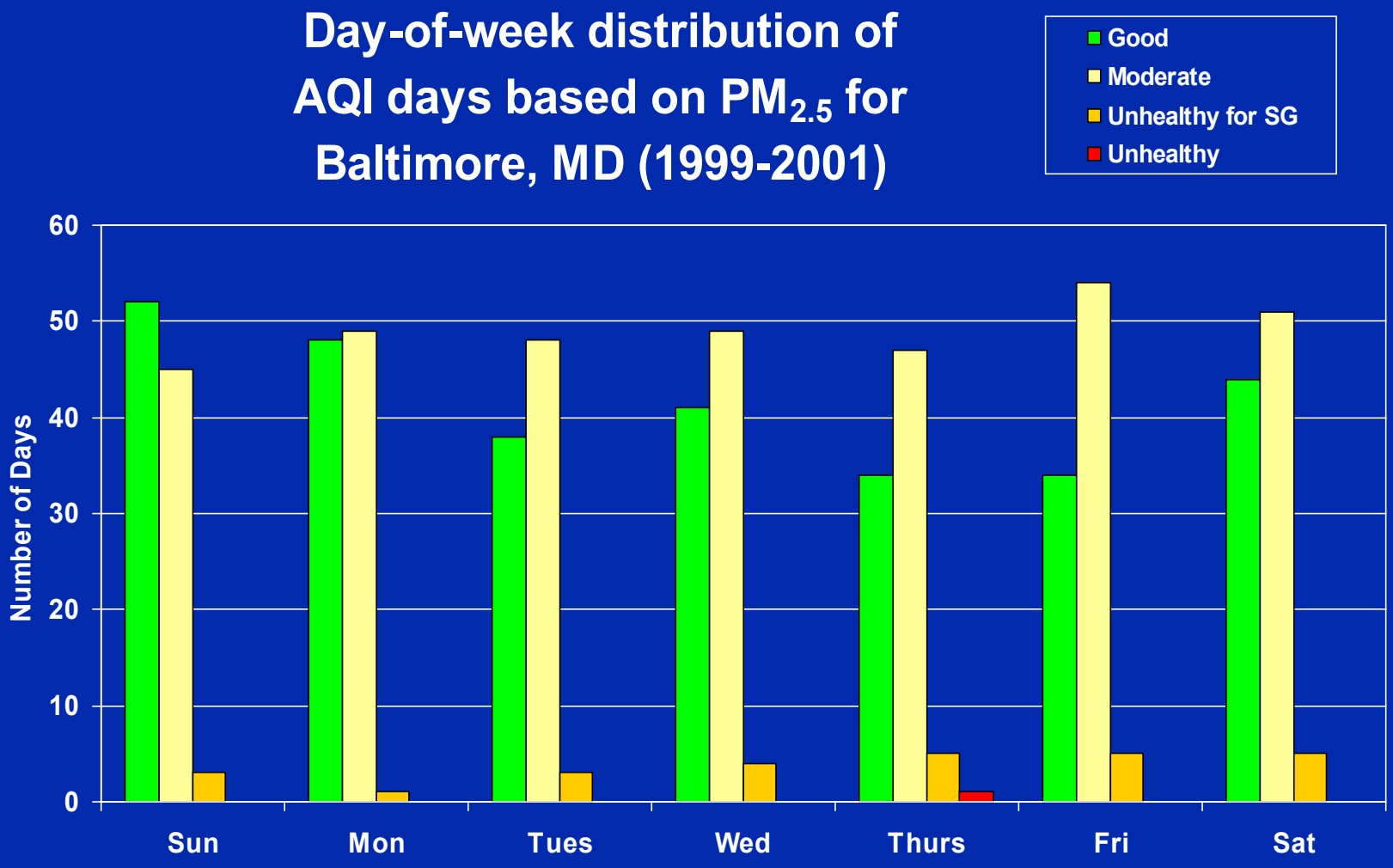
# Climatology

- Study of average and extreme weather (or air quality) conditions
- Examines past conditions for
  - Maximum and minimum values
  - Duration of poor air quality days
  - Average number of days in each AQI category
  - Diurnal patterns
  - Day-of-week distributions
  - Weekend/weekday distributions
- Helps guide forecasters

# Climatology – Example (1 of 2)



# Climatology – Example (2 of 2)



# Climatology

## Strengths

- Easy to develop and update
- Helps guide the forecast

## Weaknesses

- Not a stand-alone method
- Does not provide pollutant concentrations

# Statistical – Examples

- Develop statistical relationship between historical air quality and meteorological data
- Several methods
  - Regression
  - Classification and Regression Trees (CART)

# Statistical – Example (1 of 3)

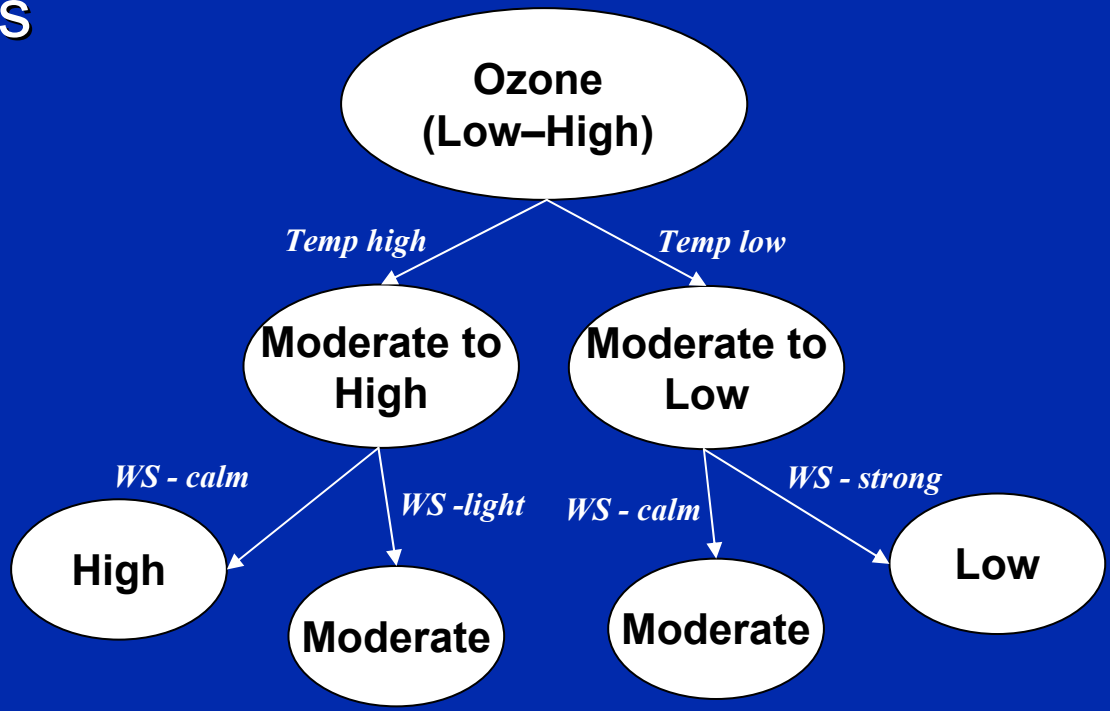
## $PM_{2.5}$ Regression Equation

$PM_{2.5}$ ($\mu g/m^3$) = 53.429 + 3.382*Holiday – 0.189*Precip – 0.31*Tmax
– 0.541*SurfaceWS + 1.008*(T@700mb – Tmin)
+ 0.838*(Stability) + 0.183*Td@700mb00Z – 0.292*WS@850mb00Z

| Variable | Description |
|---|---|
| Holiday | 1 for Valentine's Day, Martin Luther King, Jr. Day, Presidents' Day, Veterans' Day, and Super Bowl Sunday.<br>2 for Thanksgiving weekend and Christmas Eve through New Year's Day.<br>1 for weekends immediately preceding or following any of the above holidays.<br>0 for all other days. |
| Precip | Forecasted precipitation in inches during the 24-hr forecast period. |
| Tmax | Forecasted daytime maximum temperature (ºF) |
| SurfaceWS | Average resultant wind speed from 12Z to 00Z (0500 to 1700 MST) |
| T@700mb | Temperature at 700 mb at 12Z (0500 MST) (ºC) |
| Tmin | Forecasted or observed minimum temperature (ºC) |
| Stability | Temperature at 700 mb at 00Z (1700 MST) (ºC) minus the forecasted daytime maximum temperature (ºC) at the surface |
| Td@700mb00Z | Dew-point temperature at 700 mb at 00Z (1700 MST) (ºC) |
| WS@850mb00Z | Wind speed at 850 mb at 00Z (1700 MST) (m/s) |

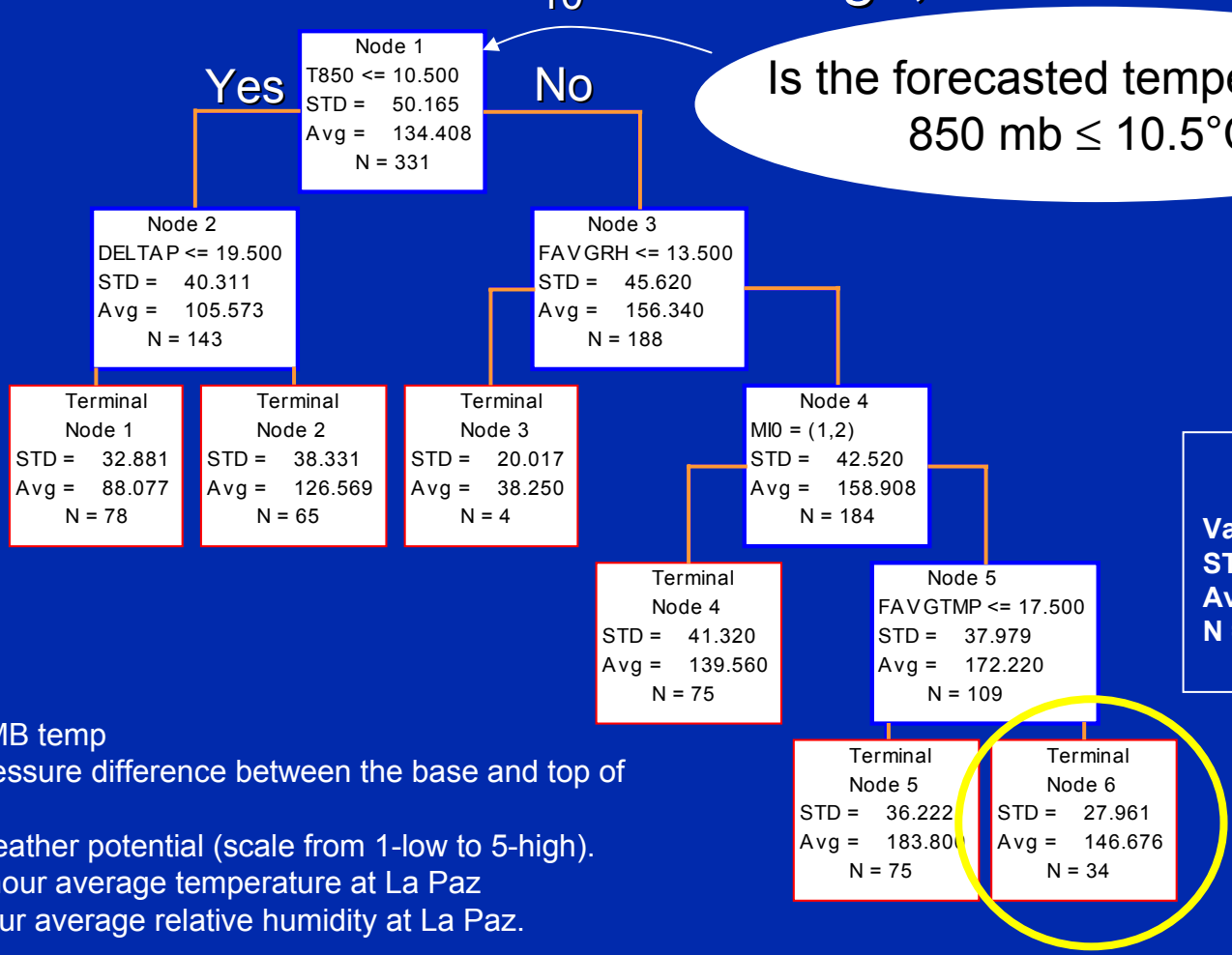
# Statistical – Example (2 of 3)

- Classification and Regression Trees (CART)
- Software develops the decision tree with human guidance
- CART splits data sets into similar and dissimilar groups



# Statistical – Example (3 of 3)

## CART classification $PM_{10}$ in Santiago, Chile




**Node x**

**Variable and criteria**
**STD = Standard deviation**
**Avg = Average $PM_{10}$ (ug/m³)**
**N = number of cases in node**

**Variables:**

*T850* - 12Z 850 MB temp
*DELTAP* - the pressure difference between the base and top of the inversion
*MI0* - Synoptic weather potential (scale from 1-low to 5-high).
*FAVGTMP* - 24-hour average temperature at La Paz
*FAVGRH* - 24-hour average relative humidity at La Paz.

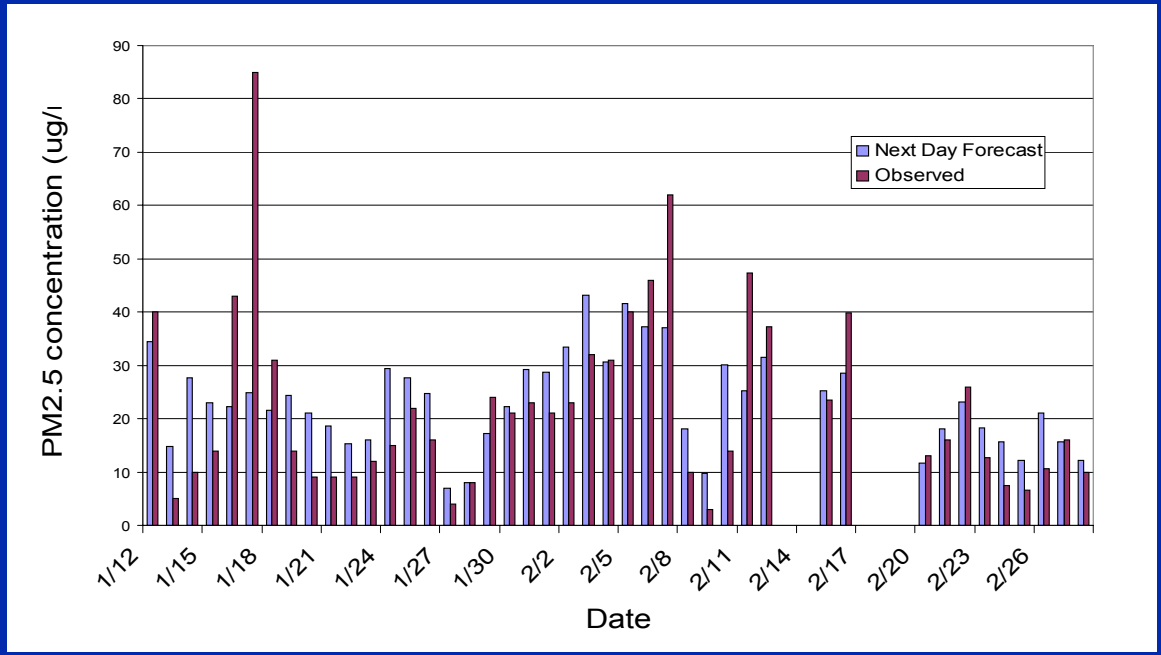
Cassmassi (1999)

# Statistical

Strengths

- Easy to operate
- Provides concentration or AQI category estimates

Salt Lake City, UT
Next Day $PM_{2.5}$ Forecast and Observed $PM_{2.5}$

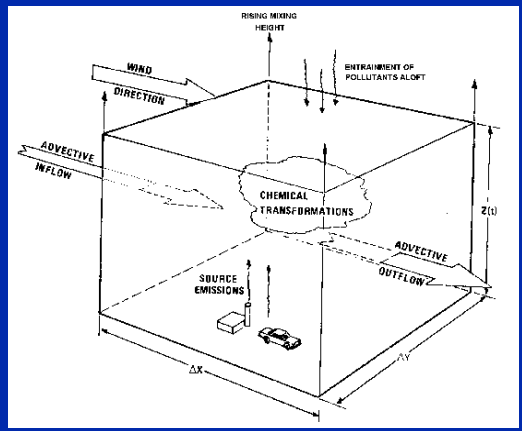


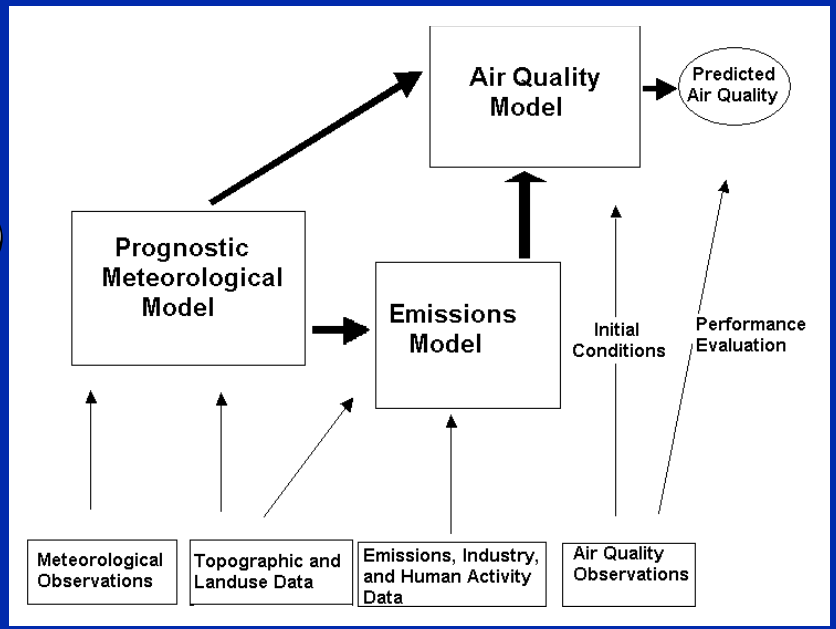

Weaknesses

- Requires more expertise to develop
- Must be updated every three years or so
- Tends to underpredict peak concentrations

# Modeling

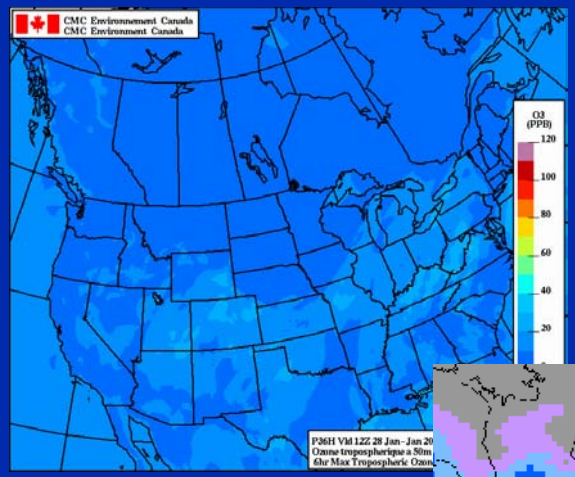
- Numerically model the processes
- Requirements:
  - Gridded emission model
  - Meteorological model forecasts
  - Photochemical model
  - Other supporting data
    - Land use
    - Boundary conditions (air quality)
  - Computer resources
- More sources of uncertainty



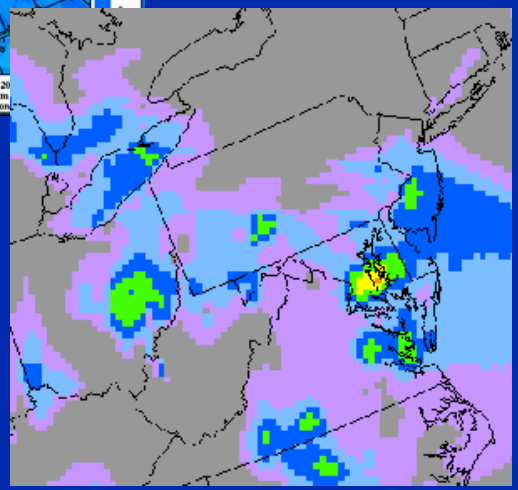



# Modeling – Example (1 of 2)

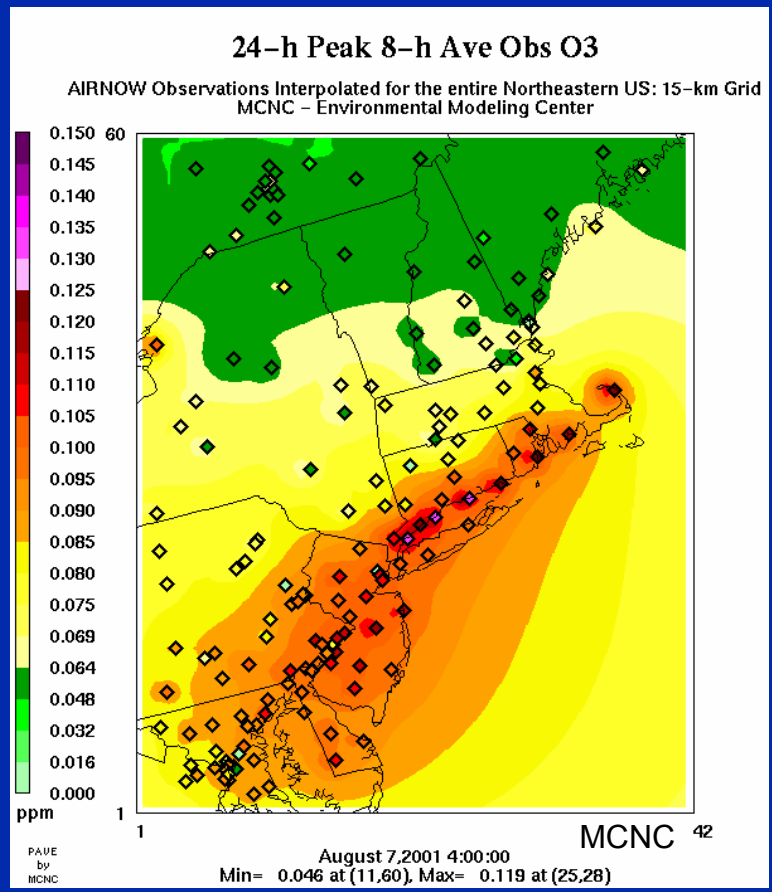
Research and operational modeling is being conducted by a number of organizations: Environment Canada, MCNC, NOAA, Ohio State, Sonoma Technology, Inc., SUNY-Albany, Washington University




Environment Canada



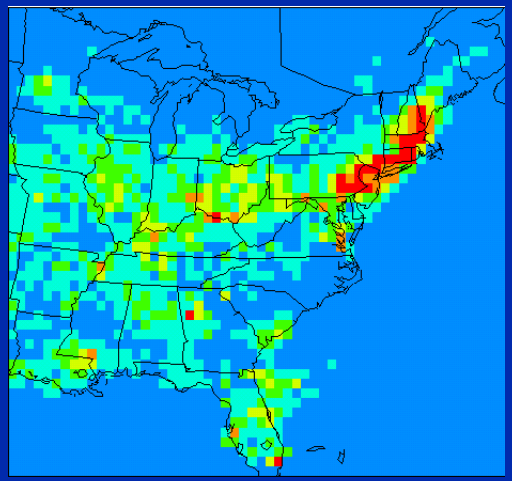
SUNY-Albany



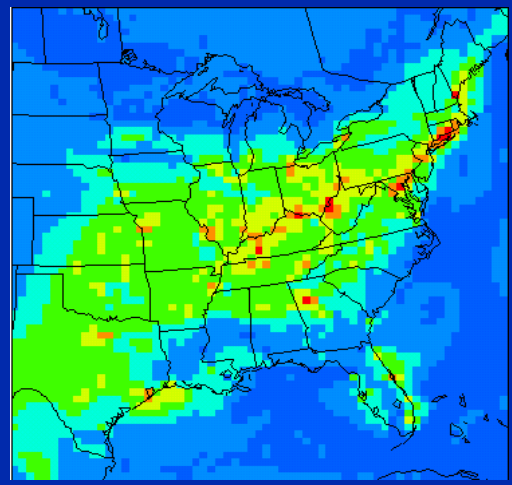
# Modeling – Example (2 of 2)

Ozone concentration forecasts and observations on August 5, 2002, at 0400 EDT

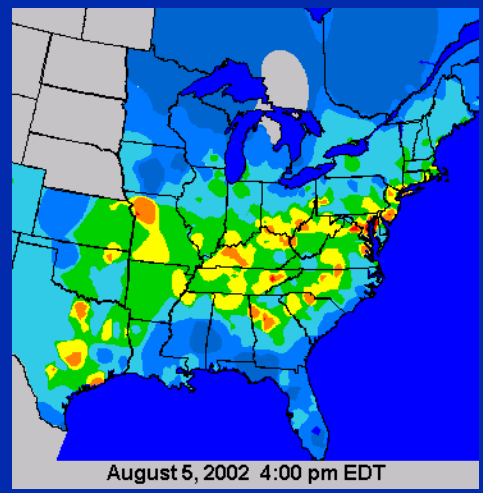
**NOAA ARL's HYSPLIT**

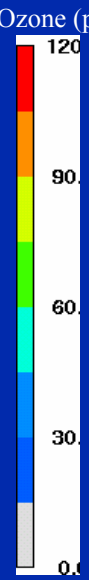


**MCNC's MAQSIP**



**AIRNow Data**



# Modeling

Strengths

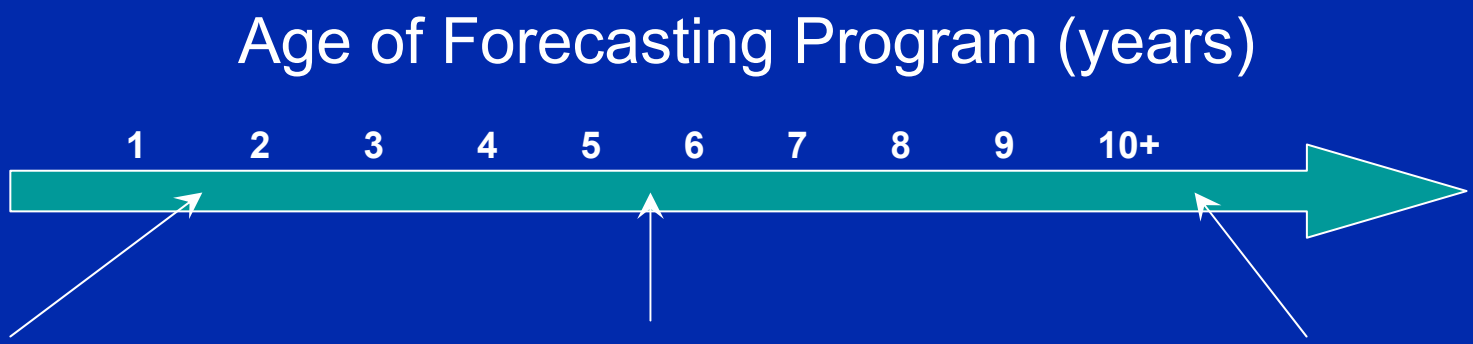
- Based on atmospheric and chemistry physics
- Provides forecasts in areas without monitors
- Helps further explain air quality processes
- Provides better temporal resolution than other methods

Weaknesses

- High level of expertise and funding needed to develop, operate, and improve*
- Requires substantial computer resources

* NOAA is planning to run a model and provide forecast guidance to air quality forecasters.

# Evolution of Forecasting Programs




- Limited data
- Limited experience and understanding
- One forecasting tool/technique
- Modest accuracy

- Good historical data set
- Good understanding
- Modest experience
- Several forecasting tools/techniques
- Higher accuracy

- Excellent historical data set
- Detailed understanding
- Extensive experience
- Many forecasting tools/techniques
- Highest accuracy

# Summary

Air Quality Forecasting Tools

- Data availability and quality
- Develop understanding
- Develop tools
- The more tools the better

- Next step - Lunch
- Questions